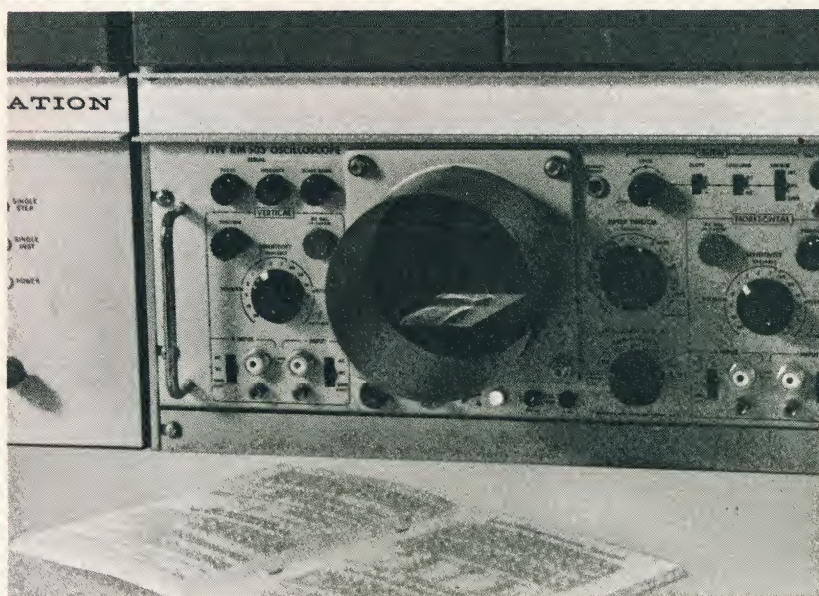
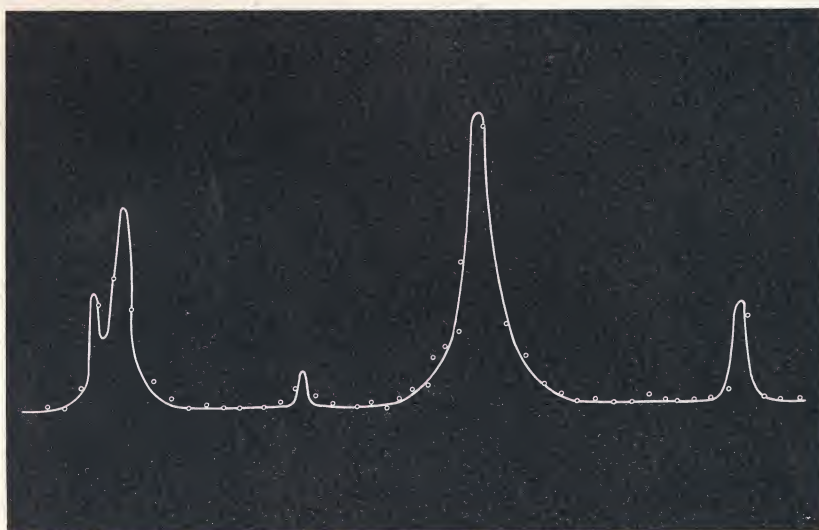


PDP MULTIANALYZER

PULSE HEIGHT/TIME OF FLIGHT



MULTICHANNEL, MULTIPARAMETER ANALYSIS WITH A GENERAL-PURPOSE COMPUTER

PDP Multianalyzers are multichannel, multiparameter laboratory systems based on Digital Equipment Corporation's modern, general-purpose Programmed Data Processor computers. Three general classes of Multianalyzers are in use: for time-of-flight studies, for pulse-height studies, and for general counting and control. They are the only commercially available, computer-integrated systems designed to meet the requirements of today's more sophisticated experiments.

These experiments demand instruments which can accept, manipulate, store, refine, and present large quantities of data to provide a statistically significant basis for the investigator's conclusions. Simple event-counting, event-recording devices expanded to handle these great numbers become too expensive, complex, and failure-prone to be built and used by most physicists.

The problem of handling masses of data, however, has already been solved in other laboratories with the active registers and random-access core memory of the high-speed, general-purpose digital computer. The computer's ability to help the physicist has, as a result, been increasingly recognized since the 1962 Grossinger Conference on Analyzers.

Until the development of the Multianalyzer, however, experimenters who wanted to use computers had to design, assemble, and maintain their own systems. Now, the physicist can buy an economical, proven, off-the-shelf system, complete with any input stages and input/output equipment he needs, all covered by one warranty and service policy.

The key advantage of Digital's Multianalyzer is flexibility: the user changes analysis modes just by reading in a new program. Thus the system can perform pulse height studies for one user and serve as a FORTRAN processor for the next. Or an experi-

menter who needs a higher per-channel count capacity than the memory word size provides can achieve any desired capacity by pairing channels with a simple revision of his program. No hardware changes are required; no other experiments are affected, since each user reads in his own program when starting.

This flexibility extends to problem-solving and other general-purpose computation. The physicist can turn quickly from gathering data to analyzing it — from controlling an experiment to performing statistical studies on the results. He no longer need be dependent on a computation center for his real-time calculations.

The computing ability of the Multianalyzer not only gives him his results sooner, it helps him insure that the results will be meaningful. In counting assignments, for example, it can generate periodic reports based on the information taken from the scalars, permitting the experimenter to evaluate the progress of a run and to vary the parameters to get maximum usefulness from the equipment.

The economy of the Multianalyzer is due only in part to its low price — \$34,000 — lower than the prices of many older, more limited computers and fixed-program analyzers. Major savings are also achieved by more efficient use of accelerator time and through the use of the system as a computer between experiments, when fixed-program machines are idle.

A further economy for growing laboratories results from the Multianalyzer's ability to use more memory as its assignments become more complex. The conventional, wired-program devices are limited to their initial channel capacity, but a Multianalyzer can be quickly and economically enlarged from an initial 4096-channel configuration to 32,768 or more. The number of channels can be doubled, for example, for a fraction of the Multianalyzer's price.

PULSE HEIGHT ANALYSIS

Digital builds Multianalyzers to perform energy-distribution studies for two types of experiments. One provides a high degree of resolution between adjacent energy levels, usually with high data taking rates. The other records data on the basis of energy versus energy, using multiple detectors, sophisticated event selection techniques, and low data rates.

To perform pulse height analyses requiring precisely distinguished energy levels, the Multianalyzer would resemble the system shown in Figure 1. The dual analog-to-digital converter forming the input stage from the detectors was specified by this system's user because he required an input stage with excellent linearity, both integral and differential. Conversion speed was of secondary importance to him.

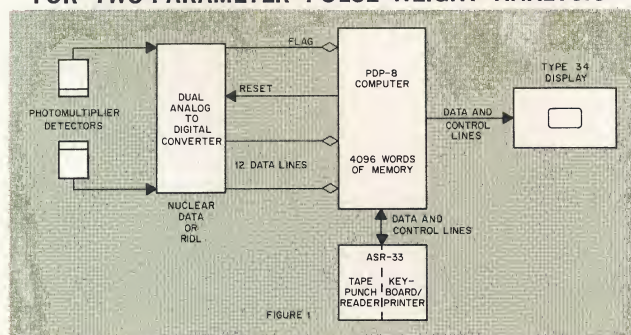
In such applications Digital uses converters of the ramp generator type made by nuclear instrumentation firms, the model specified by the user. Digital's single warranty and service policy cover the entire system.

When speed becomes the determining factor, Digital uses its own successive approximation analog-to-digital converter. It can accept an analog pulse from the detector and convert it into a 10-bit digital number (thereby selecting one of 1024 channels) in 5 microseconds.

In operation, the digital number reaching the computer on the 12 data lines from the converter is recognized by the computer as corresponding to one of the values assigned to a data word (channel) in memory. The computer takes the contents of the corresponding word, increases it by one, restores the incremented number in the same memory location, and resets the converter in anticipation of the next event. Using a data interrupt cycle, the total time required is 1.6 microseconds.

An alternate technique, when on-line analysis is not required, would feed data to the computer from paper tape, conventional magnetic tape, or Digital's DEC-tape equipment. This method permits redisplay of data, subtraction of background, normalization, and spectrum stripping.

SUGGESTED MULTIANALYZER CONFIGURATION FOR TWO-PARAMETER PULSE HEIGHT ANALYSIS



FLIGHT TIME ANALYSIS

Digital builds Multianalyzers to perform time-distribution studies for three types of experimentation: velocity measurements to determine energies, life-time measurements to determine identities of unstable particles, and time coincidence measurements to seek correlations between events occurring near each other in time. The time-of-flight Multianalyzer consists of an elapsed-time-measuring section, a data-handling and storing section, and a result-presenting section. Examples of suggested configurations are shown.

As in all of Digital's time-of-flight system designs, these can read the scalars "on the fly." This feature enables the Multianalyzer to collect data at high neutron counting rates, processing several events during each cycle of the accelerator, and it eliminates the cumbersome dead time correction steps required in systems which must halt the scaler to read it.

Digital designs and builds time-measuring sections for low-energy particle experiments, those dealing with channel widths down to 0.1 microsecond. These units are constructed with Digital's standard, off-the-shelf System and FLIP CHIP Modules and can easily be modified by the user to meet new requirements.

For high-energy applications requiring channel widths down to 0.01 microsecond, Digital equips the Multianalyzer with commercially available elapsed time units. Digital's warranty and service policy cover the complete system.

A typical input section has the following characteristics:

<i>time channels per detector</i>	8, 16, 24, etc. to 512
<i>channel width (microseconds)</i>	1, 2, 4, 8, etc. to 128
<i>data handling capacity</i>	10,000 events per second, periodic
<i>event-pair resolution</i>	2.0 microseconds

This unit is intended for multiple-detector use, but it can be equipped with one detector initially and others added later. All detectors can count 512 time channels, operating simultaneously and delivering their data to memory on a first-come, first-served basis. The maximum time range (512 channels times 128 microseconds per channel) is 65,536 microseconds. No delays are provided in the basic unit, but through the use of our modules any system pulse can be readily delayed any specified interval from 2.5 microseconds to 0.2 seconds.

The basic clock frequency is derived from a 4-mega-cycle crystal-controlled oscillator with an accuracy of 0.01 per cent from -20° to 55°C . The accuracy of the scalars is 0.150 microsecond (independent of clock accuracy).

ALTERNATE DATA INPUT TECHNIQUES

The input unit can be connected to the computer, directly addressing and incrementing the memory location associated with a given channel, as the system in Figure 2 does. This technique, utilizing the encoder to generate the correct memory address, permits the Multianalyzer to accept and store data at average and instantaneous data rates equal to the memory cycling rate, up to 620,000 events per second.

The technique represented by the system in Figure 3 uses a portion of memory as a derandomizing buffer. The input data is deposited in the form of a list in a reserved block of memory. Later, the list is processed to select and increment the corresponding channels. The advantage of this technique is that it relegates address selection to the computer, rather than the encoder. The investigator can thus manipulate the data and perform various functions on it — compensating for instrument error for example, or using algebraic or boolean selection rules — before storing

it. In this mode, the instantaneous data rate equals the memory cycling rate; average data rates depend on the processing routine.

The list processing mode lends itself well to channel compression, providing extensive detail about the high energy time channels without eliminating coverage of other channels. As the rundown goes out in time, more and more time intervals can be associated with each memory register.

For example:

Data from the first	512 time intervals goes into the first 512 memory words.
Data from the next	512 time intervals goes into the next 512 memory words.
Data from the next	1,024 time intervals goes into the next 512 memory words.
Data from the next	2,048 time intervals goes into the next 512 memory words.
Data from the next	4,096 time intervals goes into the next 512 memory words.
Data from the next	8,192 time intervals goes into the next 512 memory words.
Data from the next	16,384 time intervals goes into the next 512 memory words.
	32,768
	3,584

This allocation of memory permits the investigator to gather data from 32,768 time channels in only 3,584 words of memory.

SUGGESTED MULTIANALYZER CONFIGURATIONS FOR TIME OF FLIGHT ANALYSIS

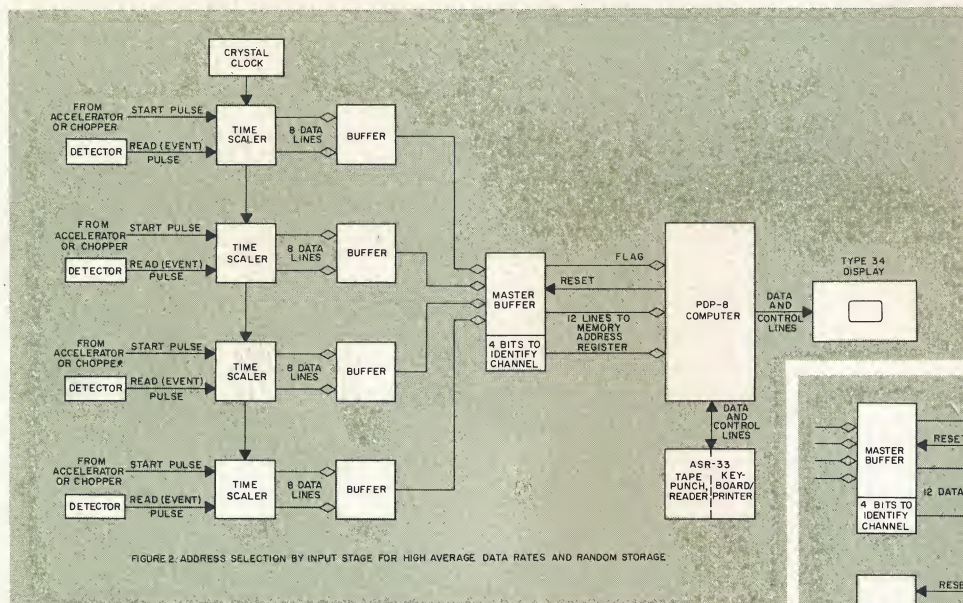


FIGURE 2. ADDRESS SELECTION BY INPUT STAGE FOR HIGH AVERAGE DATA RATES AND RANDOM STORAGE

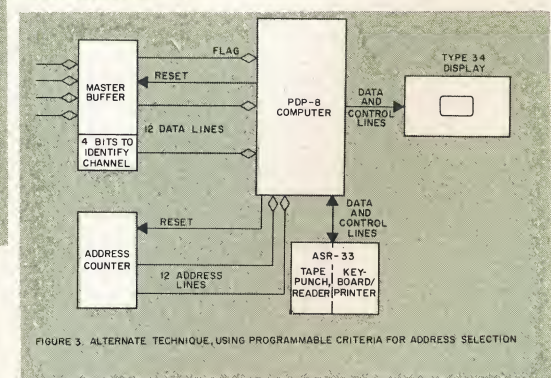


FIGURE 3. ALTERNATE TECHNIQUE, USING PROGRAMMABLE CRITERIA FOR ADDRESS SELECTION

COUNTING AND CONTROL

For counting and control applications, the computer is tied in with a spectrometer or diffractometer. The computer will provide pulses under program control to cause the movement of stepping motors and, where necessary, will read position encoders to determine absolute position. Intensity data can be counted

directly in the computer's memory, or, for very high counting rates ($> 620,000$ per second), an external scaler will be provided that can be read under program control. Scalers with rates up to 30 megacycles are offered.

COMPUTERS

The computers used in Digital's Multianalyzers are the PDP-7 and PDP-8. Both use integrated circuits and 2- and 10- megacycle logic.

The PDP-8, a compact computer with core memory, performs input/output transfers at rates up to 620,000 words per second. Memory size is from 4096 to 32,768 words. The machine is a single address, fixed word, stored program computer with a built-in data channel and a complete field-tested programming system. Its instructions, like those for the PDP-7, permit the operator to specify any input/output, logic, or arithmetic operation.

PDP-8 Specifications:

Word length	12 bits
Arithmetic	parallel, binary
Memory	1.6 μ sec, 4096 to 32,768 words
Computing rate	310,000 additions per second
In-out transfer rate	620,000 words per second

The PDP-7 is a larger and more powerful computer with a 1.75-microsecond core memory cycle time. Its speed, order code, and programming system make the computer excellent for both real-time applications and general data processing.

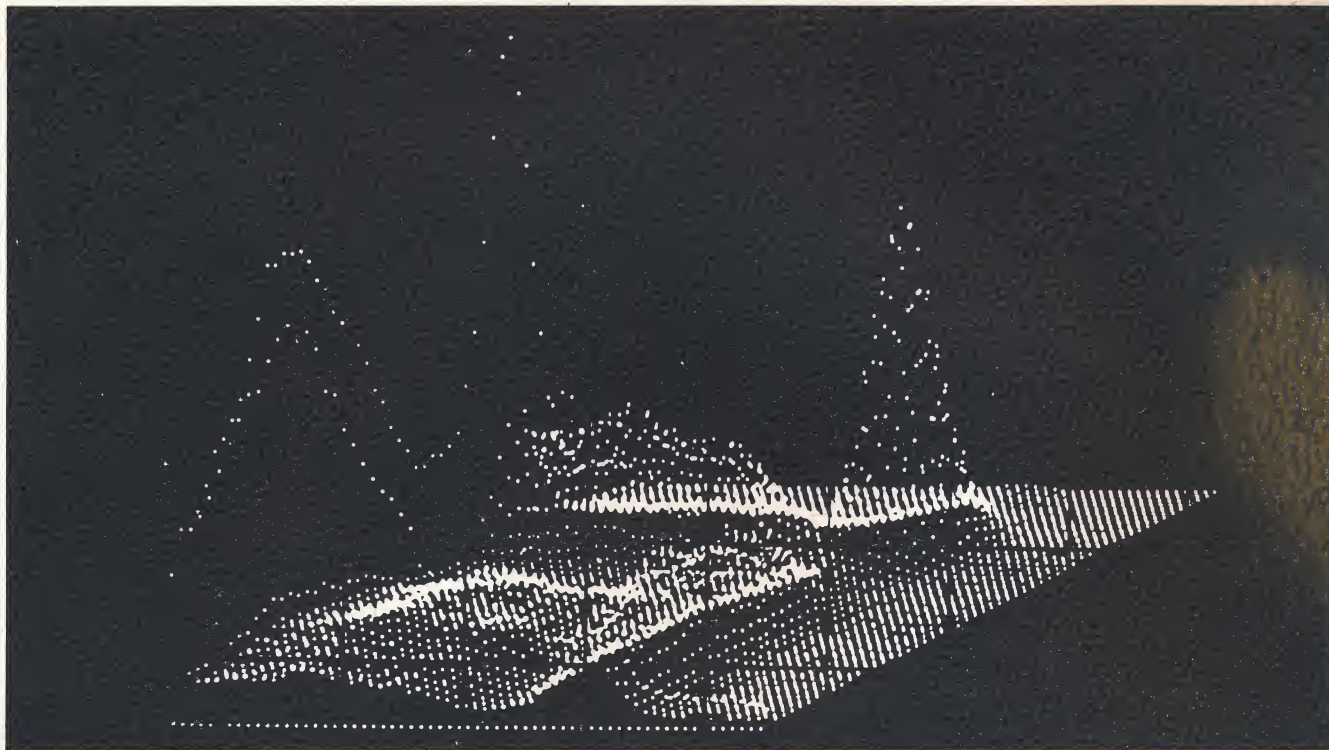
PDP-7 Specifications:

Word length	18 bits
Arithmetic	parallel, binary
Memory	1.75 μ sec, 4096 to 32,768 words
Computing rate	285,000 additions per second
In-out transfer rate	570,000 words per second

Often, computing center power is desirable. Digital offers a 36-bit word length computer, the PDP-6, to meet these requirements. All interfaces for nuclear instrumentation are available on the PDP-6.



Programmed Data Processor - 8



Isometric Display of Pulse Height Analysis Data

PROGRAMMING THE MULTIANALYZER

Multianalyzer programming systems are designed to make the full, general-purpose data processing capability of the computer immediately available to each user. Because the low prices of the instrument bring it within reach of many persons new to high-speed computing, the programming systems are designed to simplify and accelerate the learning process. At the same time, they incorporate many sophisticated features to interest the experienced programmer, the ability to mix assembly and FORTRAN statements, for example.

The systems include FORTRAN libraries and compilers, symbolic assemblers and loaders, symbolic editing and debugging programs, floating point and multiple precision routines, mathematical function subroutines, and various input/output, utility, diagnostic, and maintenance programs.

Some of the unique analysis features readily provided by various existing programs for the Multianalyzer include:

1. Teleprinter copy showing the number of gamma ray pulses or particles counted at each energy level;
2. Cathode ray tube displays: linear, contour, isometric (as above), or any other the experimenter chooses to program; markers can be added to the linear displays under program control, and the areas between them can be expanded for viewing, the data they enclose can be printed, or the data

can be integrated and printed;

3. Printout of memory contents in any easily programmed register order or format; the two parameter data printout is in the form of a matrix, for example, with the matrix elements labeled for ready identification of regions of interest;
4. Data discrimination based on mathematically expressible criteria to eliminate unwanted information and reduce the data base to the most significant events;
5. The full capability of a general-purpose computer at the experimenter's command for data reduction techniques such as peak area integration, spectrum stripping, curve fitting, and any mathematical analysis that he may choose.

In addition to the programming system and the experiment analysis programs furnished with the Multianalyzer, users of PDPs have access to the growing DECUS library of utility programs, routines, and other material. DECUS (for Digital Equipment Computer Users' Society) was formed to promote an effective interchange of this information. Principal channels for this flow are a monthly technical newsletter, periodic meetings, and the published proceedings of its frequent symposiums and seminars.

Training courses for those who will program, operate, and maintain the Multianalyzer are included in its basic price.

ACCESSORIES

Because the Multianalyzer is based on a true general-purpose computer, it can operate a wide selection of general-purpose devices used in experimentation or for computation. In addition to punched card, drum, disc, and printing equipment, the devices listed below are of particular usefulness in the laboratory.

HIGH SPEED PERFORATED TAPE READER AND CONTROL TYPE 750

Senses 8-hole perforated paper or Mylar tape photoelectrically at 300 characters per second.

HIGH SPEED PERFORATED TAPE PUNCH AND CONTROL TYPE 75

Punches 8-hole tape at 63.3 characters per second.

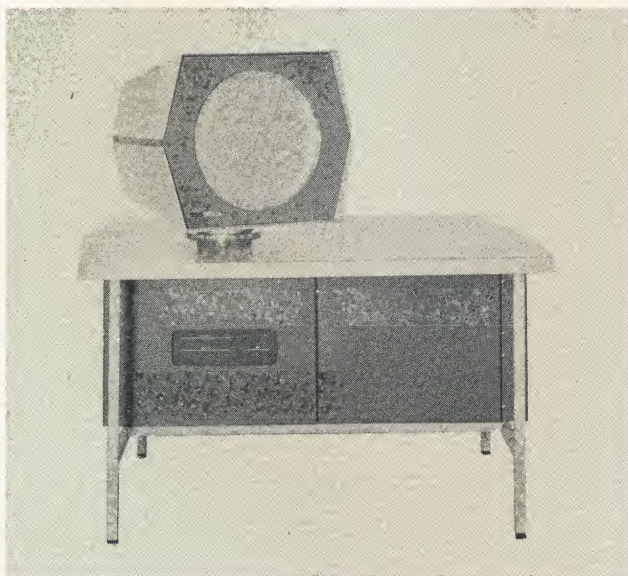
PROGRAMMED MAGNETIC TAPE TRANSPORT AND CONTROL TYPE 580

Reads and writes IBM-compatible tape at 13,334 characters per second. Recording density can be selected by the user.

EXTENDED ARITHMETIC ELEMENT TYPE 182

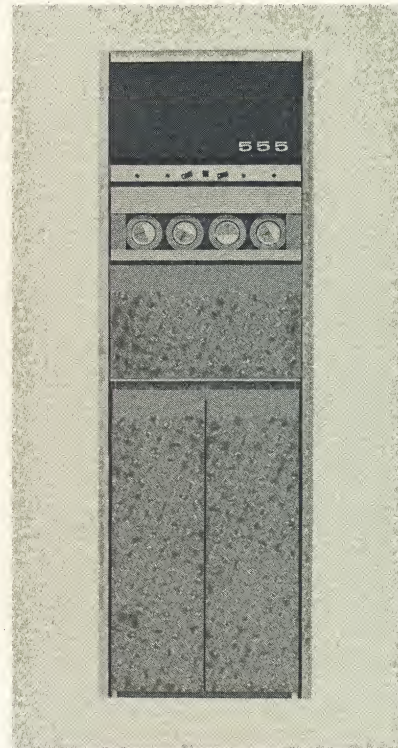
Performs high-speed multiplication and division, normalization, and other scaling operations. Multiplication times are 20 to 66 microseconds; division, a maximum of 45 microseconds.

PRECISION CRT DISPLAY TYPE 30



Plots data point by point on 16-inch cathode ray tube. Separately variable 10-bit X and Y coordinates. Eight-level brightness register.

DUAL DECTAPE SYSTEM TYPE 550A-555



Provides a fixed address magnetic tape facility for high speed loading, readout and program updating. Consists of a Type 555 Dual Transport Unit and a Type 550A Control.

LIGHT PEN TYPE 370

Detects information displayed on a Type 30 display and inputs modifying signal to the computer.

MEMORY EXTENSION CONTROL TYPE 183

Allows expansion of the PDP-8 memory from 4096 to 32,768 words in increments of 4096 words. Can be attached to any PDP-8 without changes to the central processor.

MEMORY EXTENSION MODULE TYPE 184

Extends PDP-8 core memory by 4096 12-bit words.

OSCILLOSCOPE DISPLAY TYPE 34

Plots data point by point on differential input scopes. Ten bits per axis. May be used with Tektronix 503 or with a storage scope, Tektronix 564. Three-level brightness register and fiber optics light pen are optional.

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